

The study of double spin asymmetry ALL
in π^0 production and event structure
in the RHIC-PHENIX experiment

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Motivation of π° ALL Measurement

$$\text{Proton Spin} = 1/2(\Delta u + \Delta d + \Delta s) + \Delta g + L \quad \Delta u = u^+ - u^-$$

Barion Magnetic Moment is well understood in Flavor $SU(3) \otimes$ Spin $SU(2)$.

$$\rightarrow \Delta u + \Delta d \sim 1$$

Whereas

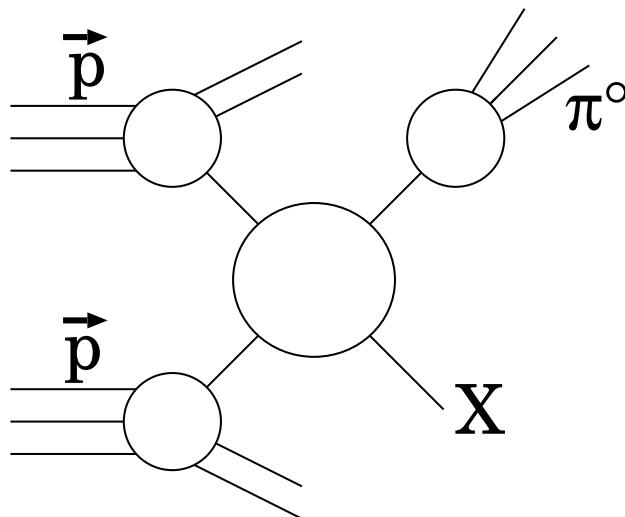
Measurement from DIS, β -decay

$$\rightarrow \Delta u + \Delta d + \Delta s = 0.1 \sim 0.3$$

What is the real proton structure?

Gluon Polarization, Δg ? Orbital Angular Momentum, L ?

Longitudinally polarized $\vec{p} \vec{p} \rightarrow \pi^{\circ}$ inclusive measurement



$$A_{\text{ALL}} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

$$\begin{aligned} &= \text{[blue wavy line] } + \text{[pink wavy line]} + \text{[green wavy line]} \\ &\propto (\Delta g)^2 \quad \propto \Delta g \Delta q \quad \propto \Delta q \Delta q \end{aligned}$$

Overview

Improvement from previous JPS

- > PID : π^0 purity up & BG down
- > Including PbGl, analyze for whole acceptance.
- > π^0 ALL final value

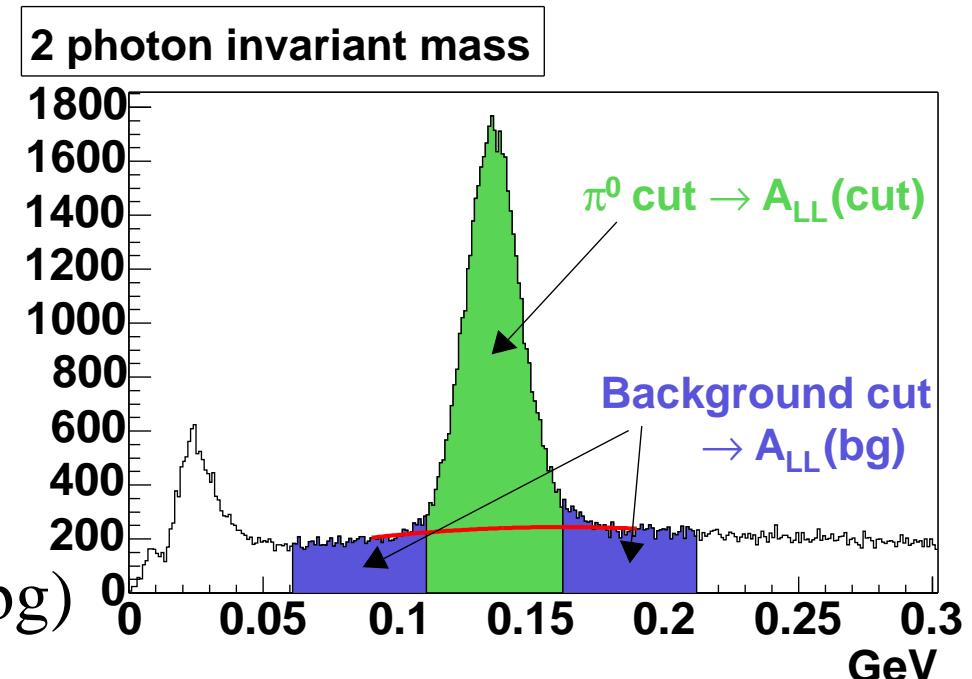
1. Calculate $A_{LL}(\text{cut})$, $A_{LL}(\text{bg})$.

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_b \cdot P_y} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$$

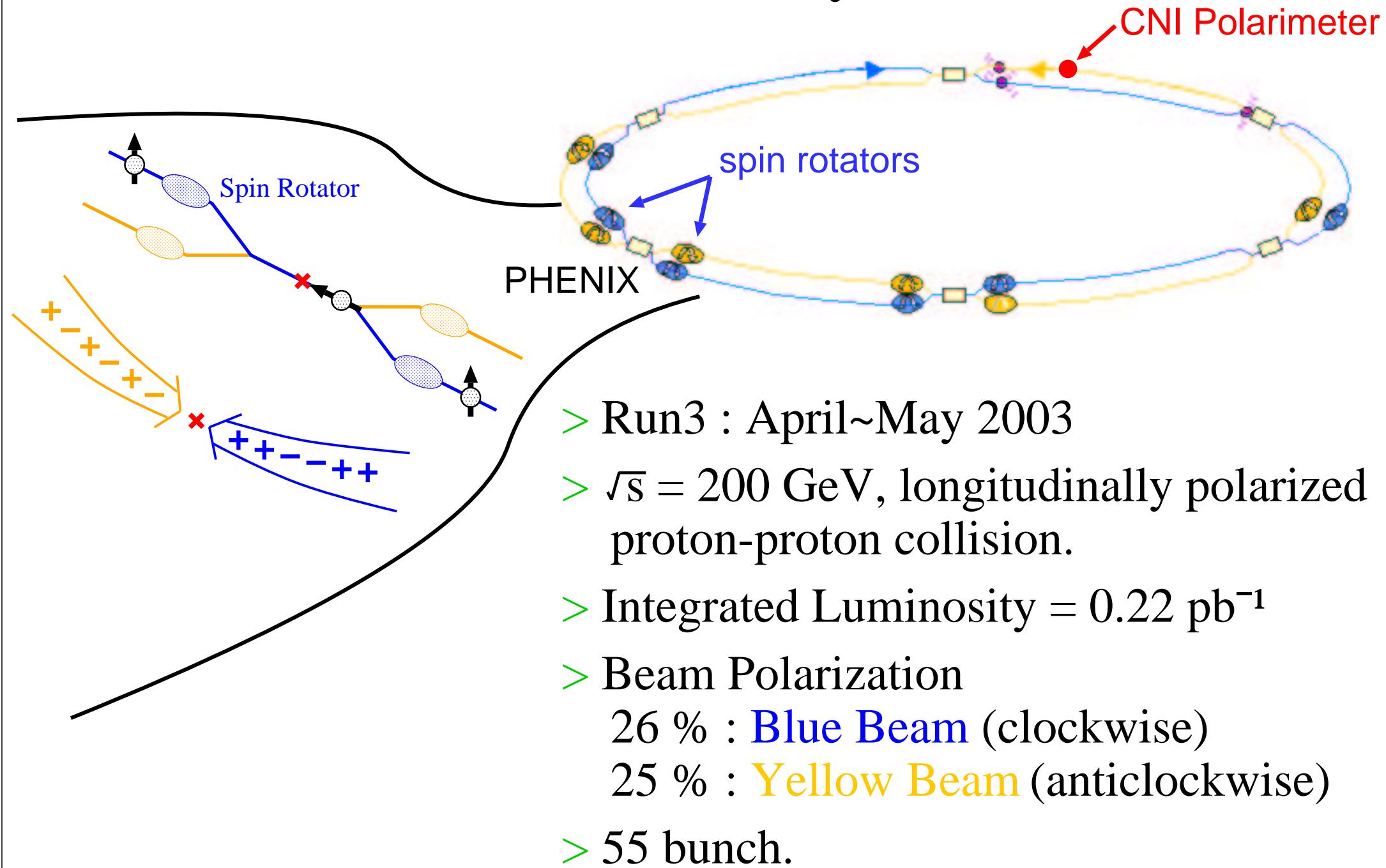
2. Get ratio of Background(wbg).

3. Subtract $A_{LL}(\text{bg})$ from $A_{LL}(\text{cut})$ to obtain $A_{LL}(\pi^0)$.

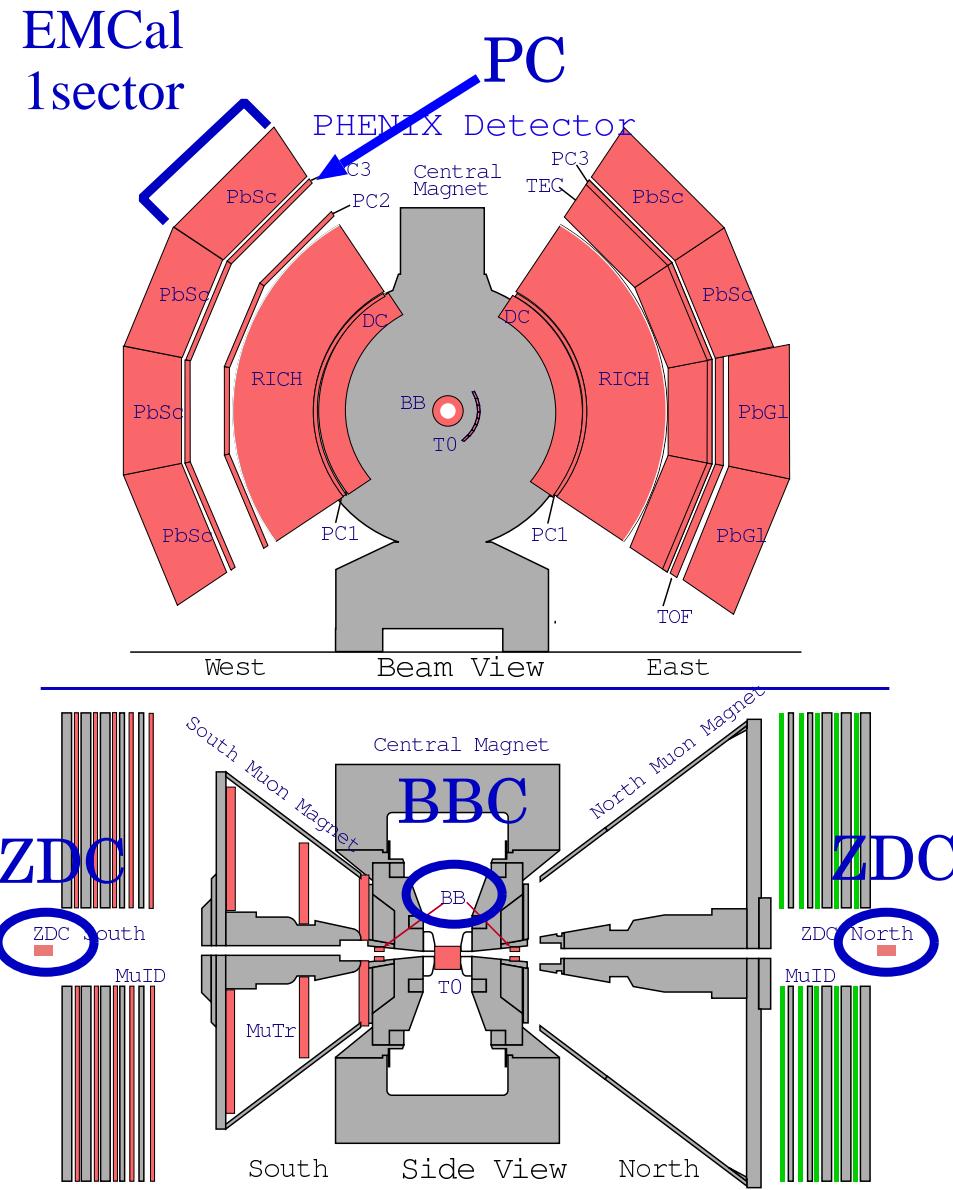
$$A_{LL}(\text{cut}) = w\pi^0 \cdot A_{LL}(\pi^0) + w\text{bg} \cdot A_{LL}(\text{bg})$$



RHIC (Relativistic Heavy Ion Collider)



PHENIX detector



Electromagnetic Calorimeter (EMCal)

> Acceptance

5m away from collision point
 $|\eta| < 0.35$, $\phi : 90+90$ degree

> PbSc(6 sectors) & PbGl(2 sectors) Fine Segmented.

$$(\Delta\eta \equiv \Delta\phi \approx 0.01)$$

> Energy Resolution

$$\text{PbSc} : 8.1\%/\sqrt{E(\text{GeV})} \oplus 2.1\%$$
$$\text{PbGl} : 5.9\%/\sqrt{E(\text{GeV})} \oplus 0.8\%$$

> Position Resolution

$$\text{PbSc} : 5.7\text{mm}/\sqrt{E(\text{GeV})} \oplus 1.6\text{mm}$$
$$\text{PbGl} : 8.4\text{mm}/\sqrt{E(\text{GeV})} \oplus 0.2\text{mm}$$

Pad Chamber (PC)

> Position Resolution ~ 1 cm

Beam-Beam Counter (BBC)

> Acceptance : $3.0 < \eta < 3.9$

Zero Degree Counter(ZDC)

> Acceptance : ± 2 mrad

PID optimization

Relation between ΔALL and π^0 Purity, Efficiency.

$$(\Delta A_{LL}^{\pi^0})^2 = \frac{1}{p^2} (\Delta A_{LL}^{\pi^0+BG})^2 + \frac{(1-p)^2}{p^2} (\Delta A_{LL}^{BG})^2 \quad p : \text{Purity}(\text{flunction of } \pi^0 \text{ in the Mass Window})$$

$$(\Delta A_{LL}^{\pi^0+BG})^2 = \frac{1}{N^{\pi^0+BG}} = \frac{p}{\epsilon} \frac{1}{N_{org}^{\pi^0}}$$

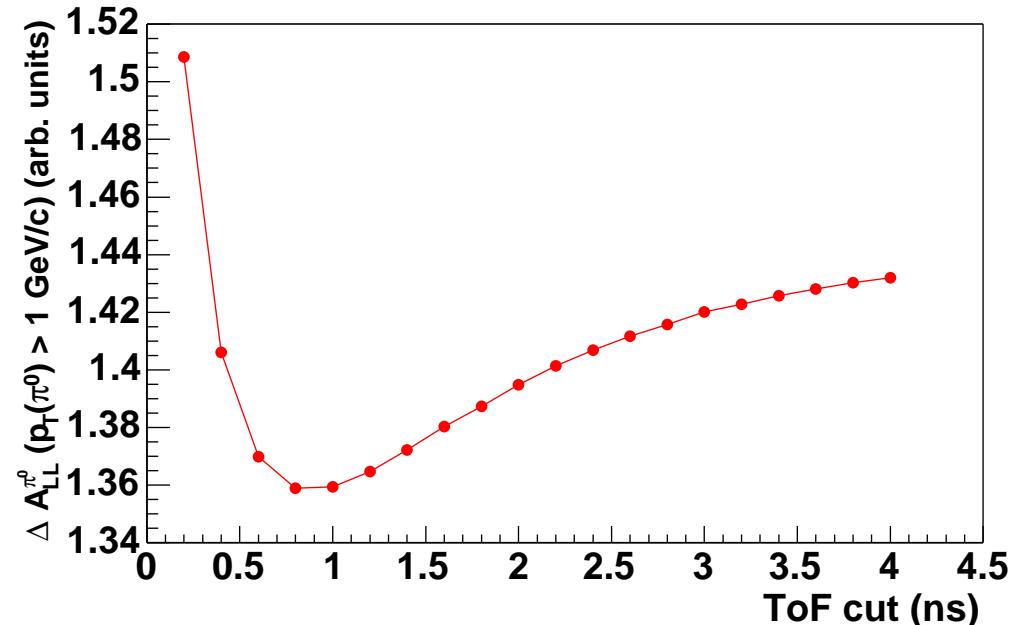
$$(\Delta A_{LL}^{BG})^2 = \frac{1}{\alpha N^{BG}} = \frac{p}{\alpha(1-p)\epsilon} \frac{1}{N_{org}^{\pi^0}}$$

$$\Delta A_{LL}^{\pi^0} = \sqrt{\frac{\alpha + 1 - p}{\alpha p \epsilon}} \frac{1}{\sqrt{N_{org}^{\pi^0}}}$$

Goal is the minimization of ΔALL .
 Different from
 Cross Section analysis.

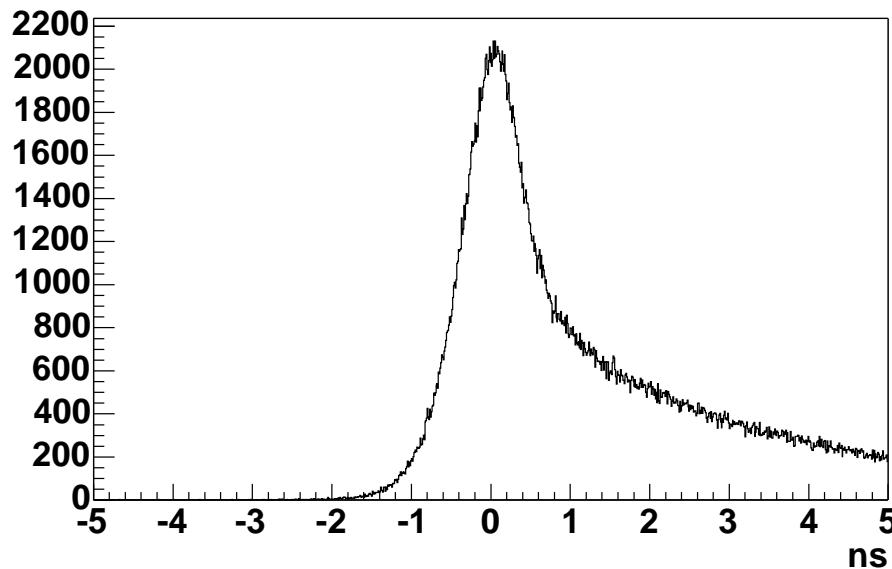
ϵ : Efficiency of π^0 by PID cut

Figure of merit for ToF cut ($0.3 < E_\gamma < 0.4 \text{ GeV}$)

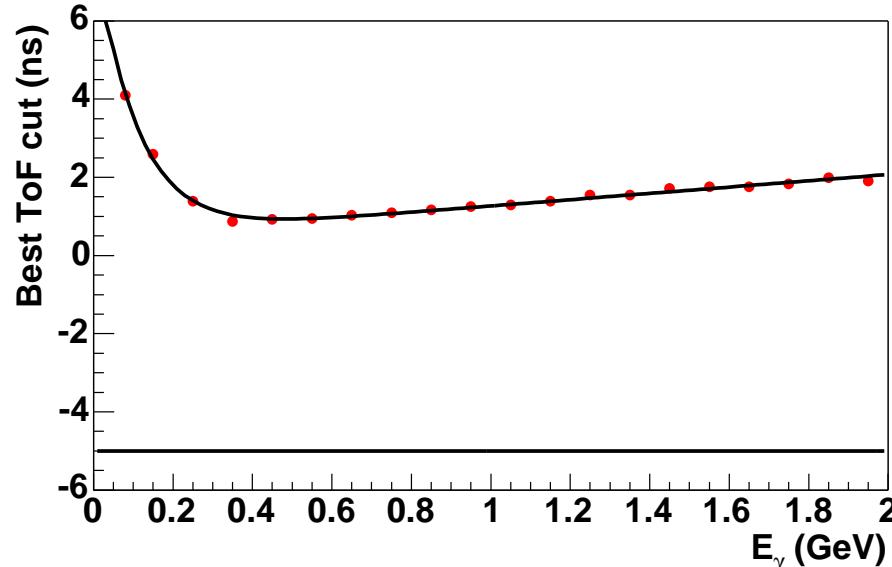


ToF Optimization

ToF distribution



Best ToF cut value



PID by time of flight from collision point to EMCal.

EMCal Time Resolution

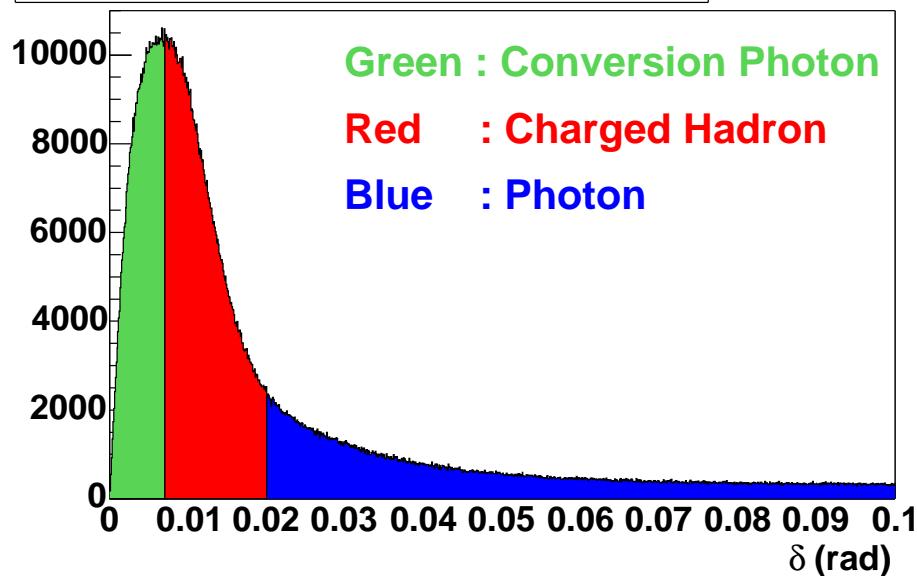
PbSc : ~0.4 ns
PbGl : ~0.5 ns

Assume the region between 2 lines as photon

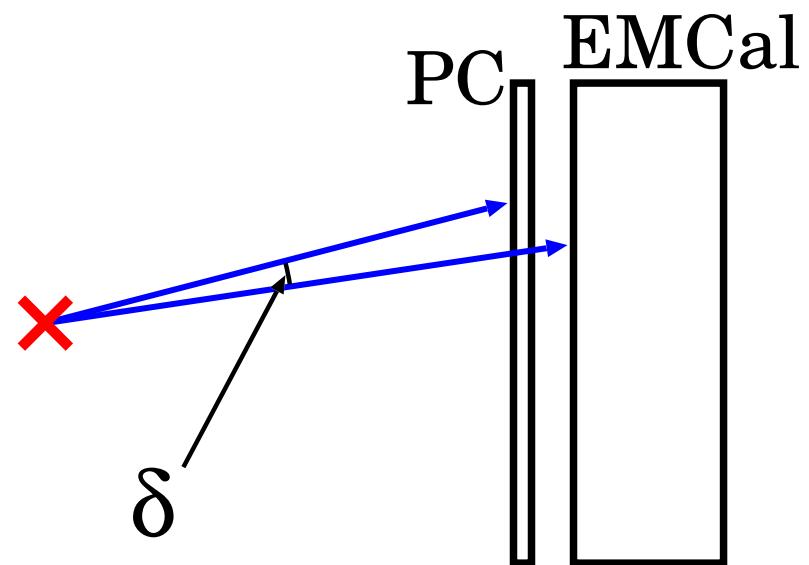
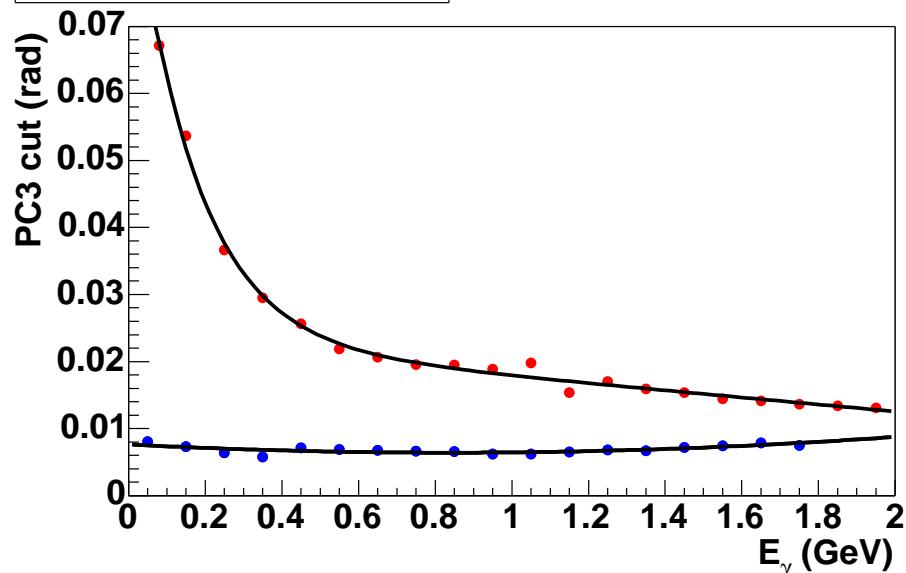
- > Worse resolution in low energy.
- > Less BG in high energy.

Charge Veto by Pad Chamber

Angle between PC hit and EMCal hit



Best PC3 cut



Keep

- Photon
- Conversion Photon

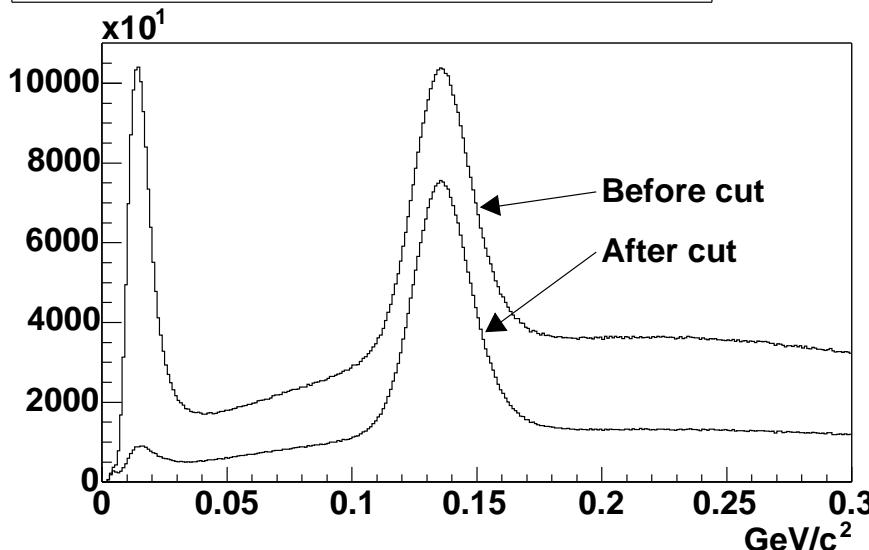
Cut

- Other Charge Particle

Cut the region between 2 lines

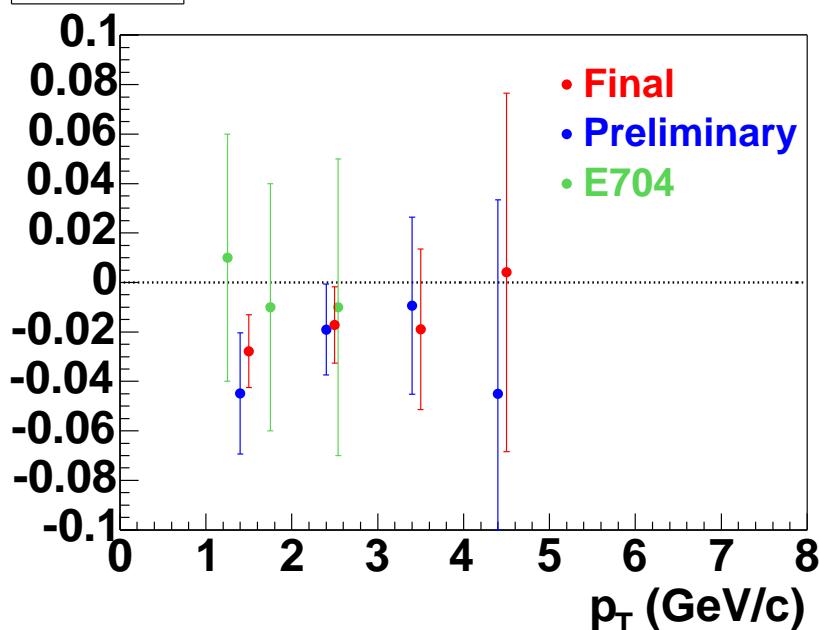
π^0 ALL Final Value

2 photon invariant mass ($1.0 < p_T < 2.0 \text{ GeV}/c$)



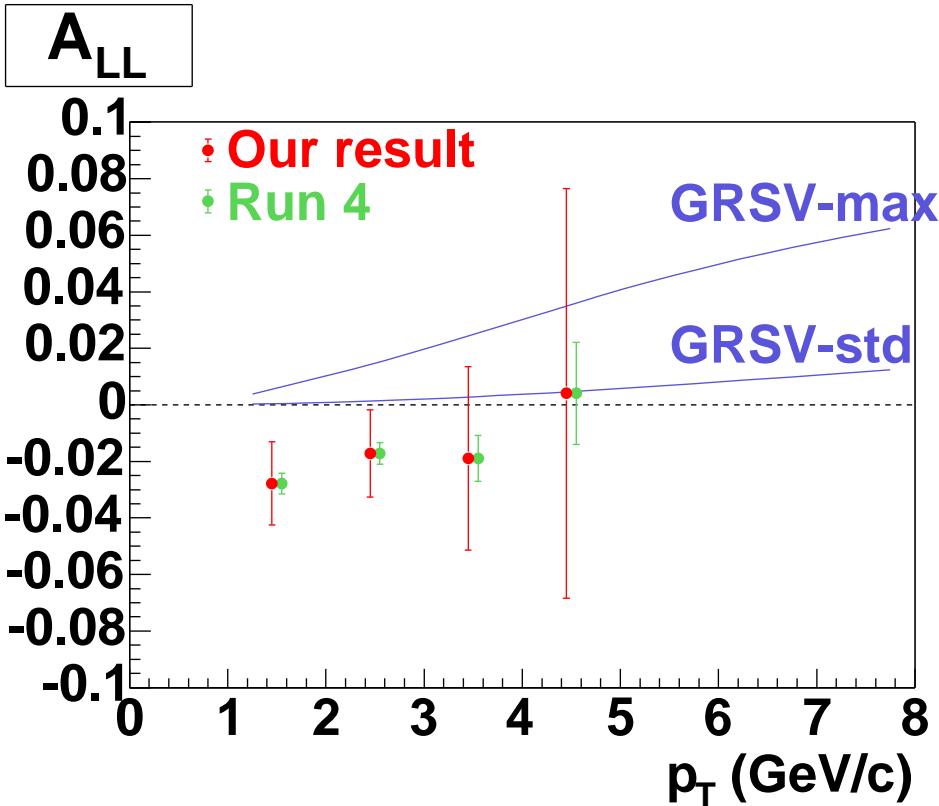
$p_T(\text{GeV}/c)$	Efficiency(%)	Purity(%)
$1 < p_T < 2$	88	$54 \rightarrow 73$
$2 < p_T < 3$	93	$75 \rightarrow 85$
$3 < p_T < 4$	96	$86 \rightarrow 91$
$4 < p_T < 5$	97	$88 \rightarrow 92$

A_{LL}



$p_T(\text{GeV}/c)$	ALL(prev)(%)	ALL(new)(%)
$1 < p_T < 2$	-4.6 ± 2.5	-2.8 ± 1.5
$2 < p_T < 3$	-1.9 ± 1.9	-1.7 ± 1.5
$3 < p_T < 4$	-0.9 ± 3.6	-1.9 ± 3.2
$4 < p_T < 5$	-4.5 ± 7.9	0.4 ± 7.2

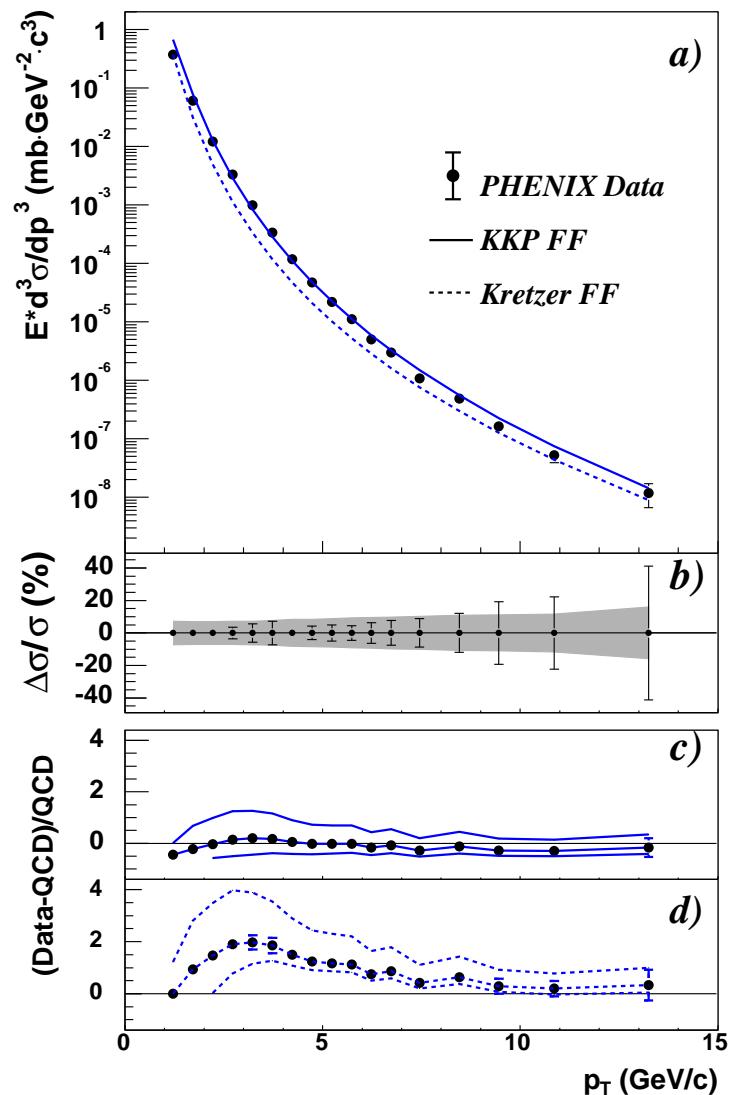
Gluon Polarization from π^0 ALL



Data support GRSV-standard.

It is difficult to obtain large negative π^0 ALL in pQCD framework in this p_T region.

More precise measurement at higher p_T is required. It is expected in run4, run5.



Conclusion

We measured π° ALL at $1 < pT < 5$ GeV, $|\eta| < 0.35$,
 $\sqrt{s} = 200$ GeV.

π° ALL has slightly negative value and support GRSV-standard model.

It is difficult to obtain large negative π° ALL in pQCD framework in this pt region.

More precise measurement at higher pt is required. It is expected in run4, run5.